

## IMAGE TAKING LENS SYSTEM

### BACKGROUND OF THE INVENTION

#### Field of the Invention

5           This invention relates to an image taking lens system, and particularly to a so-called macrolens capable of photographing an infinity object to a short-distance object of a one-to-one magnification degree in a silver halide photographic camera, a  
10 video camera, a digital still camera or the like.

#### Related Background Art

          As an image taking lens chiefly directed to the photographing of a short-distance object, there has heretofore been what is called a macrolens or a  
15 microlens (hereinafter referred to as the "macrolens").

          The macrolens, as compared with other image taking lenses such as an ordinary standard lens and a telephoto lens, is designed such that high optical  
20 performance is obtained particularly in case of the photographing of a short-distance object.

          Also, in many cases, the macrolens is utilized for the photographing of objects at a wide range of distance including not only a short-distance object  
25 but also an infinity object.

          Generally, in case of focusing from an infinity object to a short-distance object, as the

photographing magnification becomes greater, the fluctuations of various aberrations become vehement and optical performance is aggravated. Therefore, a floating method has heretofore been adopted to  
5 correct the fluctuations of the various aberrations.

In Japanese Patent Application Laid-Open No. 2-19814 (corresponding U.S. Patent No. 4,986,643) and Japanese Patent Application Laid-Open No. 2-285313 (corresponding U.S. Patent No. 5,007,720), there is  
10 disclosed a lens system capable of short-distance photographing which is comprised of three lense units, i.e., a first lens unit of positive refractive power, a second lens unit of positive refractive power and a third lens unit of negative refractive power. In  
15 these examples of the prior art, there is proposed a focusing method whereby when effecting photographing at a low magnification to a high magnification in conformity with a change in an object distance, floating is effected with the first lens unit of  
20 positive refractive power and the second lens unit of positive refractive power moved to the object side while the interval between the first lens unit and the second lens unit is changed with the third lens unit of negative refractive power kept stationary  
25 relative to the image plane.

However, in the method whereby the first lens unit is moved in case of floating, the amount of

movement of the lens unit generally becomes great.  
Therefore, to adopt this method in a camera having  
the auto focusing function, an actuator having great  
driving torque becomes necessary, or otherwise high-  
5 speed auto focusing becomes difficult.

#### SUMMARY OF THE INVENTION

The present invention has as its object to  
provide an image taking lens system of a novel  
10 construction which can quickly effect focusing from  
an infinity object to a short-distance object and  
moreover, can well correct any fluctuations of  
aberrations resulting from the focusing.

An image taking lens system according to an  
15 aspect of the present invention has, in succession  
from an object side to an image side, a first lens  
unit, a second lens unit, a third lens unit and a  
fourth lens unit, and is characterized in that in  
case of focusing from an infinity object to a short-  
20 distance object, the first lens unit is not moved,  
but the second lens unit is moved to the image side  
and the third lens unit is moved to the object side.

The principal point interval between the first  
lens unit and the second lens unit is a negative  
25 value.

# BRIEF DESCRIPTION OF THE DRAWINGS

Figs. 1A and 1B are lens cross-sectional views of an image taking lens according to a first numerical embodiment.

5 Figs. 2A and 2B are lens cross-sectional views of an image taking lens according to a second numerical embodiment.

Figs. 3A and 3B are lens cross-sectional views of an image taking lens according to a third  
10 numerical embodiment.

Figs. 4A and 4B are lens cross-sectional views of an image taking lens according to a fourth numerical embodiment.

Figs. 5A and 5B are lens cross-sectional views  
15 of an image taking lens according to a fifth numerical embodiment.

Figs. 6A and 6B show the aberrations of the image taking lens according to the first numerical embodiment.

20 Figs. 7A and 7B show the aberrations of the image taking lens according to the second numerical embodiment.

Figs. 8A and 8B show the aberrations of the image taking lens according to the third numerical  
25 embodiment.

Figs. 9A and 9B show the aberrations of the image taking lens according to the fourth numerical

embodiment.

Figs. 10A and 10B show the aberrations of the image taking lens according to the fifth numerical embodiment.

5        Fig. 11 is a schematic view of the essential portions of a single-lens reflex camera.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The image taking lens system of the present  
10    invention and an embodiment of a camera using the same will hereinafter be described with reference to the drawings. The image taking lens of the present embodiment is a macrolens of an inner focus type  
15    having an angle of view of  $24^\circ$  and an aperture ratio of F number of the order of 2.8 for use in a silver halide photographic camera, a video camera or a digital still camera, and capable of short-distance photographing up to a one-to-one magnification degree.

Figs. 1A and 1B through Figs. 5A and 5B are  
20    lens cross-sectional views of image taking lenses corresponding to first to fifth numerical embodiments which will be described later. Figs. 1A, 2A, 3A, 4A and 5A show the state when the image taking lens is in-focus on an infinity object, and Figs. 1B, 2B, 3B,  
25    4B and 5B show the state when the image taking lens is in focus on a short-distance object (one-to-one magnification of -1.0 time).

In Figs. 1A and 1B through Figs. 5A and 5B, G1 designates a first lens unit of positive refractive power (optical power = inverse number of a focal length), G2 denotes a second lens unit of negative refractive power, G3 designates a third lens unit of positive refractive power, and G4 denotes a fourth lens unit of negative refractive power. SP designates an aperture stop for adjusting a quantity of light arriving at an image plane.

10 In the image taking lenses according to the first to fifth numerical embodiments, in case of focusing from the infinity object to the short-distance object, the first lens unit G1 is not moved, but the second lens unit G2 is moved to an image side and the third lens unit G3 is moved to an object side. 15 In the image taking lenses according to the first numerical embodiment, the second numerical embodiment and the fifth numerical embodiment (Figs. 1A, 1B, 2A, 2B, 5A and 5B), the fourth lens unit G4 is not moved 20 in case of focusing, and in the image taking lenses according to the third numerical embodiment and the fourth numerical embodiment (Figs. 3A, 3B, 4A and 4B), the fourth lens unit G4 is moved as shown in case of focusing.

25 Figs. 6A, 6B through 10A and 10B show the aberrations of the image taking lenses according to the first to fifth numerical embodiments,

respectively. Figs. 6A, 7A, 8A, 9A and 10A show the aberrations when the image taking lenses are in focus on the infinity object, and Figs. 6B, 7B, 8B, 9B and 10B show the aberrations in a state (photographing  
5 magnification of -1.0 time) in which the image taking lenses are in focus on a close-range object.

Description will hereinafter be made of the features of the lens construction of the inner focus type macrolens according to the present embodiment.

10 Firstly, in the image taking lens according to the present embodiment, the principal point interval between the first lens unit G1 and the second lens unit G2 is a negative value. That is, the object side principal point of the second lens unit G2 is  
15 located more adjacent to the object side than the image side principal point of the first lens unit G1. By arranging the elements as described, while variation of aberrations caused during focusing is suppressed, wide angle of view is realized.

20 Also, in the state in which the image taking lens is in focus on the infinity object, the following condition is satisfied between the focal length  $f_2$  of the second lens unit G2 and the focal length  $f$  of the entire system:

25 
$$0.8 < |f_2|/f < 3.0 \quad \cdots (1)$$

This conditional expression (1) is an expression relating to the full length and working

distance of the lens. If the upper limit of this expression is exceeded, the focal length of the entire system in one-to-one magnification state will become short, and this will lead to a decrease in the  
5 working distance. If the lower limit of this expression is exceeded, the principal point interval between a front lens group constituted by the first lens unit G1 and the second lens unit G2 and a rear lens group constituted by the third lens unit G3 and  
10 the fourth lens unit G4 will become great and the full length of the lens will become great.

Also, in the state in which the imaging lens is in focus on the infinity object, there is the following relational expression between the focal  
15 length  $f_3$  of the third lens unit G3 and the focal length  $f$  of the entire system:

$$0.8 < |f_3|/f < 1.1 \quad \cdots(2)$$

This conditional expression (2) is an expression concerned with the full length of the lens and the  
20 correction of aberration fluctuations. If the lower limit of this conditional expression is exceeded, the refractive power of the third lens unit G3 operating as a main focusing lens unit will become too strong and therefore, the correction of the fluctuations of  
25 various aberrations will become difficult. If the upper limit of this conditional expression is exceeded, the full length of the lens will become



great. Further, the upper limit of the conditional expression (2) being exceeded means that the negative refractive power of a lens in the third lens unit G3 which is located most adjacent to the object side becomes strong, and spherical aberration will become under-corrected.

Also, a meniscus-shaped negative lens element is disposed on the side of the first lens unit G1 which is most adjacent to the object side, and further the side of the entire system which is most adjacent to the object side. Also in the state in which the image taking lens is in focus on the infinity object, there is the following relation between the focal length  $f_{11}$  of this negative meniscus lens and the focal length  $f$  of the entire system:

$$-2.0 < f_{11}/f < -0.8 \quad \cdots (3)$$

This conditional expression (3) is an expression relating to the shortening of the focal length of the entire system. If the lower limit of this expression is exceeded, the negative refractive power of the first lens unit G1 will become weak and the back focal length will become short, and if an attempt is made to secure it, the correction of the various aberrations will become difficult. If the upper limit of this expression is exceeded, the negative refractive power of the first lens unit G1 will become strong, and the correction of the

aberrations will become difficult.

The inner focus type macrolens which is the object of the present invention is achieved by the above-described construction, but to achieve still  
5 higher optical performance, when the composite focal length of the first lens unit G1 and the second lens unit G2 in the state in which the image taking lens is in focus on the infinity object is defined as  $f_{12}$  and the composite focal length of the third lens unit  
10 G3 and the fourth lens unit G4 also in the state in which the image taking lens is in focus on the infinity object is defined as  $f_{34}$ , it is preferable to satisfy the following conditions:

$$2.3 < f_{12}/f < 4.3 \quad \cdots(4)$$

15  $1.5 < f_{34}/f < 3.0 \quad \cdots(5)$

$$1.0 < f_{12}/f_{34} < 2.5 \quad \cdots(6)$$

Conditional expression (4) is an expression relating to the composite focal length of the first lens unit G1 and the second lens unit G2. If the  
20 lower limit of this expression is exceeded, it will become difficult to secure the back focal length, and if an attempt is made to secure it, the correction of the fluctuations of the various aberrations will become difficult. The lower limit of conditional  
25 expression (4) being exceeded means that the refractive power of the negative meniscus lens in the first lens unit G1 which is disposed most adjacent to

the object side is weak. On the other hand, if the upper limit of this expression is exceeded, the full length of the lens will become great.

Conditional expression (5) is an expression  
5 relating to the composite focal length of the third lens unit G3 and the fourth lens unit G4. If the lower limit of this expression is exceeded, the correction of the fluctuations of the various aberrations will become difficult, and if the upper  
10 limit of this expression is exceeded, the full length of the lens will become great.

Conditional expression (6) is an expression relating to the composite focal length of the first lens unit G1 and the second lens unit G2 and the  
15 focal length of the third lens unit G3 and the fourth lens unit G4. If the lower limit of this expression is exceeded, the correction of the fluctuations of the various aberrations will become difficult, and if the upper limit of this expression is exceeded, the  
20 full length of the lens will become great and spherical aberration will become under-corrected.

Further, when the amount of movement in case of the focusing of the second lens unit G2 from the infinity object to the closest range object is  
25 defined as  $\Delta s_2$ , and the amount of movement in case of the focusing of the third lens unit G3 from the infinity object to the closest range object is

defined as  $\Delta s_3$ , it is preferable to satisfy the following condition expression:

$$-0.5 < \Delta s_2 / \Delta s_3 < -0.3 \quad \cdots (7)$$

If the lower limit of this conditional expression is  
5 exceeded, the full length of the lens will become great.

If the upper limit of this conditional expression is exceeded, the correction of the fluctuations of the various aberrations resulting  
10 from the focusing will become difficult.

The image taking lenses according to the first to fifth numerical embodiments satisfy conditional expressions (1) and (2). The image taking lenses according to the first to fourth numerical  
15 embodiments satisfy conditional expression (3).

The image taking lenses according to the second numerical embodiment, the third numerical embodiment and the fifth numerical embodiment satisfy conditional expression (4), the image taking lenses  
20 according to the first numerical embodiment, the second numerical embodiment, the third numerical embodiment, the fourth numerical embodiment and the fifth numerical embodiment satisfy conditional expression (5), the image taking lenses according to  
25 the first numerical embodiment, the third numerical embodiment, the fourth numerical embodiment and the fifth numerical embodiment satisfy conditional

expression (6), and the image taking lenses according to the second numerical embodiment, the third numerical embodiment, the fourth numerical embodiment and the fifth numerical embodiment satisfy  
5 conditional expression (7).  
(Numerical Embodiments)

The numerical data of the first to fifth numerical embodiments will be shown below. In each numerical embodiment, the aperture stop is located  
10 between the second lens unit and the third lens unit. In the data table of each embodiment, the numbers at the left end indicates the surface numbers from the object side,  $r$  indicates the radius of curvature,  $d$  indicates the surface interval,  $nd$  indicates the  
15 refractive index for d-line, and  $rd$  indicates the Abbe number with the d-line as the reference.  $f$  indicates the focal length,  $Fno$  indicates F number, and  $\omega$  indicates a half angle of view.

Also, the values of the aforescribed  
20 conditional expressions (1) to (7) are shown in Table 1.

First Numerical Embodiment

	f=50	Fno.2.8	$2\omega=23^\circ$	
	r	d	nd	vd
1	115.00772	1.99677	1.612716	58.72
2	21.78411	9.751		
3	85.78794	4	1.804398	39.59
4	-72.70214	0.15224		
5	32.84808	4.91896	1.651597	58.55
6	-43.3562	1.84959	1.84666	23.78
7	1385.45509	Variable		
8	-166.08434	1.37137	1.882997	40.76
9	31.31431	3.7429		
10	-33.54624	2	1.639999	60.07
11	31.03576	6.53694	1.834807	42.72
12	-28.18164	Variable		
13	Stop	Variable		
14	213.35815	3.16748	1.603112	60.64
15	-47.37145	0.3955		
16	40.25073	5.5967	1.563839	60.67
17	-37.0585	1.18309	1.84666	23.78
18	-1788.00383	Variable		
19	221.14268	1.17844	1.772499	49.60
20	24.51316	0.63789		
21	24.58988	3.36048	1.761821	26.52
22	35.80335	37.91209		
	(Focusing on $\infty$ )	(Magnification:-0.5)	(Magnification:-1.0)	
d7	1.350316	4.79147	10.1534	
d12	13.0166	9.579496	4.212328	
d13	16.80352	8.348689	0.4918	
d18	0.917163	9.284323	17.22968	

Second Numerical Embodiment

	f=50	Fno.2.8	$2\omega=23^\circ$	
	r	d	nd	$v_d$
1	66.50498	2	1.806098	40.92
2	23.71183	9.83233		
3	94.52845	4	1.806098	40.92
4	-59.83555	0.15		
5	25.98714	3.5	1.696797	55.53
6	-3741.26955	1.85	1.846660	23.78
7	64.68535	Variable		
8	16401.70439	1.4	1.834807	42.72
9	24.14979	3.72463		
10	-26.17439	1.4	1.603112	60.64
11	29.02264	6.5	1.785896	44.20
12	-27.53037	Variable		
13	Stop	Variable		
14	295.43121	3	1.603112	60.64
15	-44.27573	0.15003		
16	52.38671	5	1.603112	60.64
17	-40.74572	1.8	1.84666	23.78
18	1303.01099	Variable		
19	77.63608	1.5	1.719995	50.22
20	25.91181	2.12469		
21	27.39389	3	1.717362	29.50
22	39.60108	41.45224		
	(Focusing on $\infty$ )	(Magnification:-0.5)	(Magnification:-1.0)	
d7	1.93447	5.177822	9.496911	
d12	8.89367	5.650107	1.331522	
d13	21.84553	9.013635	0.461018	
d18	0.69460	9.27902	22.07905	

Third Numerical Embodiment

	f=50	Fno.2.8	$2\omega=23^\circ$	
	r	d	nd	v d
1	150.67735	1.83680	1.612716	58.72
2	22.57346	9.58301		
3	60.27003	4	1.804398	39.59
4	-78.90792	0.14868		
5	35.74925	4.03565	1.651597	58.55
6	-48.29254	1.84764	1.84666	23.78
7	543.79648	Variable		
8	-878.88216	1.17437	1.882997	40.76
9	28.18880	3.58554		
10	-29.85656	2	1.639999	60.07
11	31.48063	6.32752	1.834807	42.72
12	-29.80371	Variable		
13	Stop	Variable		
14	216.27438	3.45184	1.603112	60.64
15	-42.42590	0.07499		
16	43.41831	6.19788	1.563839	60.67
17	-38.57082	1.12161	1.84666	23.78
18	1121.19301	Variable		
19	124.88978	1.13959	1.772499	49.60
20	24.60926	1.42352		
21	26.02916	3.59768	1.761821	26.52
22	40.26601	42.70379		
	(Focusing on $\infty$ )	(Magnification:-0.5)	(Magnification:-1.0)	
d7	1.24705	4.853858	9.898873	
d12	13.06268	9.456024	4.39846	
d13	18.34951	9.309686	0.439465	
d18	0.93710	9.519019	17.4228	



Fourth Numerical Embodiment

	f=60	Fno.2.8	2 $\omega$ =19°	
	r	d	nd	v d
1	110.95560	1.99187	1.612716	58.72
2	23.39728	8.75644		
3	101.97027	4	1.804398	39.59
4	-72.34949	0.68904		
5	33.83231	5.15590	1.651597	58.55
6	-46.82644	1.84950	1.84666	23.78
7	-9245.25134	Variable		
8	-179.79613	1.36572	1.882997	40.76
9	32.27252	4.15310		
10	-32.62375	2	1.639999	60.07
11	34.19271	7.06762	1.834807	42.72
12	-29.04183	Variable		
13	Stop	Variable		
14	306.99026	3.52797	1.603112	60.64
15	-45.22440	0.45673		
16	41.71080	5.18931	1.563839	60.67
17	-41.78514	1.17942	1.84666	23.78
18	1196.39387	Variable		
19	235.02405	1.18460	1.772499	49.60
20	24.53977	1.23699		
21	25.46594	3.37421	1.761821	26.52
22	38.51150	44.79209		
	(Focusing on $\infty$ )	(Magnification:-0.5)	(Magnification:-1.0)	
d7	1.38246	4.371874	9.029904	
d12	12.98057	9.991211	5.333271	
d13	17.15679	8.413058	0.858992	
d18	0.93291	9.142834	17.26707	

Fifth Numerical Embodiment

	f=50	Fno.2.8	$2\omega=23^\circ$	
	r	d	nd	$v_d$
1	75.25994	2	1.806098	40.92
2	21.42281	9.71656		
3	184.06695	4	1.806098	40.92
4	-54.01108	0.15000		
5	27.77456	3.50000	1.696797	55.53
6	-209.01663	1.85000	1.84666	23.78
7	111.51020	Variable		
8	-499.73309	1.40000	1.834807	42.72
9	28.82495	4.04915		
10	-30.01746	1.40000	1.603112	60.64
11	34.90119	6.50000	1.785896	44.20
12	-26.33523	Variable		
13	Stop	Variable		
14	841.21561	3.00000	1.603112	60.64
15	-50.93167	0.15003		
16	60.02894	5.00000	1.603112	60.64
17	-35.42829	1.80000	1.84666	23.78
18	-311.03709	Variable		
19	78.61014	1.50000	1.719995	50.22
20	26.64005	2.24373		
21	26.92617	3.00000	1.717362	29.5
22	34.61848	41.62772		
	(Focusing on $\infty$ )	(Magnification:-0.5)	(Magnification:-1.0)	
d7	1.96208	4.970468	9.207935	
d12	8.04793	5.039448	0.802418	
d13	22.04871	10.95185	0.804663	
d18	0.80749	11.9044	22.05156	

Table 1

Numerical Embodiment	Conditional Expression						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	2.7	0.84	- 0.86	2.24	2.17	1.03	- 0.54
2	1.4	0.92	- 0.91	4.14	1.47	2.81	- 0.35
3	1.8	0.85	- 0.84	3.52	1.66	2.12	- 0.48
4	2.1	0.76	- 0.81	2.20	2.17	1.02	- 0.47
5	2.7	1.03	- 0.73	2.33	2.07	1.13	- 0.34

An embodiment in which the aforescribed image  
5 taking lens is applied to an optical apparatus will  
now be described with reference to Fig. 11.

Fig. 11 is a schematic view of the essential  
portions of a single-lens reflex camera. In Fig. 11,  
the reference numeral 10 designates an  
10 interchangeable lens provided with the image taking  
lens system (macrolens) 1 of the present invention.  
The image taking lens 1 is held by a lens barrel 2  
which is a holding member. The reference numeral 20  
denotes a camera main body which is constituted by a  
15 quick return mirror 3 for upwardly reflecting a beam  
from the interchangeable lens, a focusing plate 4  
disposed at the image forming position of the image  
taking lens 1, a pentaprism 5 for transforming an  
inverted image formed on the focusing plate 4 into an  
20 erect image, an eyepiece 6 for observing the erect  
image therethrough, etc. The reference numeral 7  
designates a photosensitive surface on which is  
disposed silver halide film or the light receiving  
surface of a solid state image pickup element

(photoelectric conversion element) such as a CCD sensor or a CMOS sensor. During photographing, the quick return mirror 3 is retracted from an optical path and an image is formed on the photosensitive surface 7 by the image taking lens 1.

As described above, the image taking lens of the present invention can be applied to an optical apparatus such as a single-lens reflex camera.